U.S Department
of Transportation
**Federal Aviation Administration**

# Advisory Circular

FAR GUIDANCE

**Subject:** SURGE AND STALL CHARACTERISTICS OF AIRCRAFT TURBINE ENGINES

**Date:** 12/6/85
**Initiated by:** ANE-110
**AC No:** 33.65-1
**Change:**

1. PURPOSE. This advisory circular (AC) provides guidance material for acceptable means of demonstrating compliance with the requirements of Part 33 of the Federal Aviation Regulations (FAR) relative to surge and stall characteristics and thrust response of turbine engines. These guidelines do not constitute a regulation and are therefore not mandatory. Additionally, they are not necessarily the only means of showing compliance with applicable airworthiness requirements. This material applies to large, high bypass ratio turbofan engines.

2. RELATED FAR SECTIONS. Part 33, Sections 33.65 and 33.73 of the FAR.

3. BACKGROUND. This AC, relating to engine certification substantiation procedures, is intended to assist in establishing uniformity in the certification process and in the pre-certification test planning by defining certain terms and procedures which are in common use throughout the industry.

4. DEFINITIONS. The definitions are provided to give clarity in understanding the intent of this AC.

a. Engine Surge: Surge is a response of the entire engine which is characterized by large fluctuation in engine pressures with significant flow reduction or reversal in the compression system.

b. Engine Stall: Stall is a flow breakdown at one or more compressor airfoils which can cover a wide variety of pressure disturbances producing mild fluctuations or stable reductions in engine pressure and flow.

c. Engine Surge Margin: Surge margin is calculated from the quantitative difference between the value of a selected engine parameter at the normal steady-state operating line and the value of that parameter on the verge of stall. This margin is usually expressed in percent of compressor pressure ratio at constant corrected flow. Other parameters may be used as long as they are clearly defined.

5. RELATIONSHIP TO AIRCRAFT CERTIFICATION PROCEDURES.

a. The current engine and aircraft certification procedures and the FAR have evolved based upon the experience of past programs. By application of the current procedures, the engine is usually certificated prior to testing in the intended aircraft. This provides the aircraft manufacturers with a pretested powerplant upon which to base aircraft certification testing.

b. In applying these procedures to a given aircraft/engine certification, changes to the engine or aircraft may be required to improve the engine operating characteristics as part of the certification of the aircraft/engine combination. These changes, as they affect the engine as certificated under Part 33 of the FAR, are handled as engineering changes to the engine type design with the approval of the Federal Aviation Administration (FAA). By application of these procedures, any undesirable installed engine operating characteristics that become apparent during the aircraft certification process are addressed. Corrective action is then implemented prior to issuance of the aircraft type certificate.

c. The maximum inlet pressure distortion for which it has been demonstrated that blade stresses are acceptable and operation is free from hazardous surge should be included in the engine installation manual as a basis for establishing compatibility of the airframe inlet.

6. APPROACH.

a. Goals. By a combination of tests or tests and analyses, the engine manufacturer should show that the engine characteristics are such that the engine will start and operate free from hazardous surge and with sufficient thrust response throughout the engine's operating envelope. In addition, the engine should be capable of withstanding a surge at takeoff power, without structural failure, significant overtemperature, flameout, damage sufficient to preclude recovery of engine power, or damage that will lead to subsequent failure.

b. Plans. Prior to the initiation of engine surge and stall certification testing, the engine manufacturer should present the FAA with a plan which outlines his approach to demonstrating compliance with the regulations. This plan should describe the engine configuration, engine operating requirements, component and engine test facilities, test procedures and analyses. This plan should address the determination of the starting capability and transient response of the engine, including transient acceleration and deceleration characteristics both with and without engine bleed air and power extraction. The plan may propose to use analyses, sea level tests or altitude tests. The engine operating requirements should be based on past experience with similar engine types, including inlet distortion and recovery effects, since the performance characteristics of the engines are predicated on the efficient matching of inlet and engine operating characteristics. In satisfying the takeoff surge recovery requirement, unplanned surges encountered during certification testing and/or surge experience with similar hardware may be considered.

c. Analyses. Quantitative evaluations of the estimated levels of surge margin and engine stability and response should be performed throughout the anticipated flight environment. A computer model of the engine may be used in this evaluation to augment results obtained by other primary techniques, such as engine and/or component tests and analyses. However, prior to acceptance of computer modeling, the applicant will be expected to present validation that the model has been successfully used to predict actual test points. The evaluation will normally account for those factors which change engine component surge lines and/or their operating lines, thus affecting engine surge margin and/or thrust response. For example, the evaluation will normally consider (but not be limited to) the effects of:

(1) Engine service deterioration.

(2) Maximum allowable combinations of compressor/turbine matching due to build tolerances.

(3) Maximum allowable combinations of rigging tolerances for variable geometry, bleeds, and control functions.

(4) Maximum allowable combination of slue rates for variable geometry bleeds and control functions.

(5) Mach number.

(6) Altitude (Reynolds number effects).

(7) Inlet distortion effects.

(8) Ingestion of heavy rainfall within the operating envelope (Reference AC 20-124).

(9) Ingestion of runway water under takeoff and idle power (Reference AC 20-124).

(10) Power transients (slow to snap), such as from flight idle to maximum power.

The above effects can occur both in isolation and in combination. Possible interactions should be recognized and accounted for in the analysis. The rationale for including or excluding any factor in the evaluation should be presented and normally supported by test or operational experience.

d. Compliance Testing. Verification testing is required to demonstrate compliance. Since engine certification generally precedes aircraft certification, any engine compliance testing is done using generalized conditions that encompass the anticipated aircraft environment. Selection of these conditions should be based on the engine manufacturer's past experience and paragraph 6.c., Analyses.

(1) To accomplish engine compliance testing, including transient operating characteristics, an appropriate combination of ground test, flight test, and/or the use of altitude test facilities is acceptable.

(2) The objective of altitude testing is to determine the effects of the aircraft environment. The testing procedure should include the following:

(i) A quantitative determination, by ground level engine testing or preferably in an altitude test facility, of the component operating line levels and the transient operating characteristics, including acceleration and deceleration. The surge, stall and flameout boundaries will normally be defined by test or test and analysis.

(ii) The use of a computer model or other means to perform a quantitative analysis of the operating characteristics identified by the above testing and analysis over the complete operating envelope of the engine. As noted in paragraph 6.c., Analyses, validation of the computer model will be expected.

(iii) The basis of this analysis should be used to select altitude demonstration conditions. The scope of testing should include the range of anticipated aircraft altitude and engine power lever transients. In situations where the test facility precludes testing under some of the desired conditions, analysis should be performed to evaluate the engine operating characteristics in the anticipated aircraft environment. However, analysis or computer modeling should not be the exclusive methods presented for altitude demonstration during basic engine certification.

(3) The capability of the engine to withstand a rotating stall and/or surge, depending on an anticipated instability occurrence during operation at takeoff power, for a period of time which is required for a crew to take corrective action, should be substantiated. Demonstration, which may be based on instabilities occurring during the development program, should include the ability of the engine to run at rated takeoff power without exceeding limits following the rotating stall and/or surge and by examination of the actual hardware.

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